Effect of Water Temperature and Air Stream Velocity on Performance of Direct Evaporative Air Cooler for Thermal Comfort

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Abstract. The aim of this work was to determine the effects of water temperature and air stream velocity on the performance of direct evaporative air cooler (DEAC) for thermal comfort. DEAC system requires the lower cost than using vapor compression refrigeration system (VCRS), because VCRS use a compressor to circulate refrigerant while DEAC uses a pump for circulating water in the cooling process to achieve thermal comfort. The study was conducted by varying the water temperature (10\textdegree C, 20\textdegree C, 30\textdegree C, 40\textdegree C, and 50\textdegree C) at different air stream velocity (2.93 m/s, 3.9 m/s and 4.57 m/s). The results show that the relative humidity (RH) in test room tends to increase with the increasing of water temperature, while on the variation of air stream velocity, RH remains constant at the same water temperature, because the amount of water that evaporates increase with the increasing water temperature. The cooling effectiveness (CE) increase with the increasing of air stream velocity where the higher CE was obtained at lower water temperature (10\textdegree C) with high air velocity (4.57 m/s). The lower room temperature (26\textdegree C) was achieved at water temperature 10\textdegree C and air stream velocity 4.57 m/s with the relative humidity 85.87%. DEAC can be successfully used in rooms that have smoothly air circulation to fulfill the indoor thermal comfort.

INTRODUCTION

The cool fresh air for domestic and commercial use can be provided mechanically using the air conditioning (AC). The use of AC equipment will increase energy consumption in conjunction with the increasing amount of carbon emissions released into the air atmosphere. Evaporative cooling is equipment that uses water as the cooling medium for air [1-5]. An evaporative air cooler (EAC) cools the air by evaporating water. As the water evaporates into the air, the result is an off air and water molecules. Evaporation of water requires heat, so energy or latent heat taken from the air molecules - so the actual temperature of the air drops. Evaporative Air Cooler technology originated from the concept of air cooling with water media. Where evaporative refrigeration is a component that serves to transfer heat from air, water or another object by absorbing the heat of evaporation of refrigerant. This study aimed to determine the effect of temperature changes on the cooling medium Evaporative Air Cooler [1].

Peng et al. [3] study about the application of evaporative cooling in the hot humid area. The study proved that the evaporative cooling can save energy consumption and improve the thermal environment compared by the conventional refrigeration system. Other than that, the model of direct evaporative cooling has been developed by Mohammad [4]. The simulation of this model showed that the direct evaporative cooling can satisfy the need of comfort condition. In automotive application Alahmer [5] did the research to determine the effect of direct evaporative cooling on automotive air conditioning. This evaporative cooler can minimize consumption of fuel and lower the pollutants. As the difficulties to collect accurate data for outdoor experiments due to the natural conditions, the laboratory experiments were more reliable to produce more accurate data. The experimental method is designed to more closer to outdoor conditions [6]. The potential of application the evaporative cooling
in Australia also indicate the significant advantages. Among different eight capital and different climates shows that the use of this system was success to reduce energy consumption [7].

S. D. Antonellis et al. [8] investigated the cross flow indirect evaporative cooling system on the effects of variation of water flow rate, humidification nozzles setup and secondary air temperature, humidity and flow rate. They study showed the performance is slightly dependent on number and size of nozzles, but it is highly affected by the flow rate of water. X. She et al. [9] investigated the air flow patterns of evaporative cooling and dehumidification process for a hybrid refrigeration system and findings the beneficial for the system design and optimization. A. K. R. Abed [10] presented the performance of direct evaporative cooler as the effect of operating parameters and findings both effectiveness and exergy efficiency affected by relative humidity more than another key variable.

In this research, the effect of water temperature and air stream velocity to the evaporative cooling system was investigated. For acquiring the data, the experimental study was conducted by varying water temperature 10°C, 20°C, 30°C, 40°C and 50°C and air stream velocity variations 4.57 m/s, 3.90 m/s, and 2.93 m/s. All the data was used to determine relative humidity and the decreasing of water mass caused by evaporation.

### EXPERIMENTAL APPARATUS AND METHODOLOGY

This experimental study of an evaporative cooling system aimed to investigate relative humidity, the effectivity and amount of vaporized water. The experiment varied the water temperature 10°C, 20°C, 30°C, 40°C and 50°C, with low, medium, and high air stream velocity 2.93 m/s, 3.90 m/s, 4.57 m/s respectively. Figure 1 [11] shows the schematic diagram of Direct Evaporative Air Cooler (DEAC) including a parameter set up for the temperature of DEAC system. The data was collected by employing dry bulb thermometer and wet bulb thermometer positioned at front and back of the fan. Other than that, the dry bulb and wet bulb thermometers also positioned in the cooling room.

![Figure 1. Schematic diagram of DEAC with variable speed fan and manual control of water temperature (modified from [11])](image)

Table 1 [12] shows the variations of air stream velocity data in average for three wind speed velocity, where the low (1), medium (2) and high (3) speed velocity are 2.93 m/s, 3.90 m/s and 4.57 m/s, respectively. The variations of air stream velocity are used in this study as a parameter for findings the best performance of DEAC.

The procedures for data collection of DEAC are as follows:

1. The temperature of water is set in accordance with the experiment temperature.
2. Evaporative cooler apparatus is turned on.
3. Wet bulb temperature and dry bulb temperature is measured.
4. The data is collected every 10 minutes.
5. All steps are repeated for different temperature and air stream velocity variation.
6. Turn off the apparatus
Table 1. Variations of air stream velocity/wind speed [12]

<table>
<thead>
<tr>
<th>No</th>
<th>Low Speed (1) (2.93 m/s)</th>
<th>Medium Speed (2) (3.90 m/s)</th>
<th>High Speed (3) (4.57 m/s)</th>
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<tr>
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<td>3.80</td>
<td>2.43</td>
</tr>
<tr>
<td>Avg</td>
<td>2.93 m/s</td>
<td>3.90 m/s</td>
<td>4.57 m/s</td>
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</tbody>
</table>

RESULT AND DISCUSSION

The effect of water temperature as cooling media vs Relative humidity of DEAC on the variations of air stream velocity for low speed, medium speed, and high speed are shown in Fig. 2 – 4, respectively. The figures show that the lowest room temperature is 26°C. As the initial condition, the initial temperature of room temperature was 30°C, that shows the temperature of the room can be decreased about 4°C. The humidity of air is 85.87% at speed 4.57 m/s and the temperature of the cooling medium 10°C.

According to ASHRAE, a comfort zone for relative humidity is about 19.8% - 79.5% [13], if it is compared to the experimental result, 85.87%, the humidity is higher. As an initial condition of relative humidity 74.92%, the utilize of the apparatus is obviously can increase the relative humidity. Thus, this apparatus should be used in the room that has better air circulation to maintain humidity exist in acceptable condition.

![FIGURE 2](image)

**FIGURE 2.** The RH vs water temperature at low air stream velocity (2.93 m/s)

![FIGURE 3](image)

**FIGURE 3.** The RH vs water temperature at medium air stream velocity (3.90 m/s)
Figure 5 shows the efficiency of DEAC reach a peak at cooling media temperature 10°C with air stream velocity 4.57 m/s by 98.18%. In contrast, the lowest efficiency is 66.32% at cooling media temperature 50°C with air stream velocity 2.93 m/s. It reveals that the higher the cooling media temperature, the higher output temperature can be generated, therefore, the efficiency decreases.

Figure 6 shows that the highest rate of evaporation is 0.000398 kg/s at cooling media temperature 50°C. Whereas the lowest rate of evaporation is 0.0005 kg/s at cooling media temperature 10°C. This experiment indicates that the higher cooling media temperature, also the higher rate of evaporation. It is caused water temperature approach its boiling temperature; which indicates that the water will vaporize faster. Otherwise, if water temperature approaches the freezing temperature, the water will be difficult to vaporize.
Figure 7 shows that the lowest average room temperature is 27.71°C at cooling media temperature 10°C and air velocity 4.57 m/s. Whereas the highest average room temperature is 28.16°C with cooling media temperature 50°C and air velocity 2.93 m/s. These results exist as high cooling media temperature will lead to increasing of output temperature. Meanwhile, at lower cooling media temperature the output temperature will be lower.

CONCLUSION

The effect of water temperature and air stream velocity on the performance of direct evaporative air cooler for thermal comfort has been presented. The relative humidity (RH) in test room tends to increase with the increasing of water temperature, while on the variation of air stream velocity, RH remains constant at the same water temperature, because the amount of water that evaporates increase with the increasing water temperature. The cooling effectiveness (CE) increase with the increasing of air stream velocity where the higher CE was obtained at lower water temperature (10°C) with high air velocity (4.57 m/s). The lower room temperature (26°C) was achieved at water temperature 10°C and air stream velocity 4.57 m/s with the relative humidity 85.87%. The DEAC can be successfully used in rooms that have smoothly air circulation to fulfill the indoor thermal comfort.

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